What happens in twilight zone:
3D or aerosol effect?

Wenbo Sun
Center for Atmospheric Sciences, Hampton University

Norman G. Loeb
Atmospheric Sciences, NASA Langley Research Center

-CERES-MODIS data show cloud and aerosol correlation.

-MISR data show reflectance increase approaching clouds.

-Possible reasons.

-Active measurement can avoid 3D and cloud contamination effect.

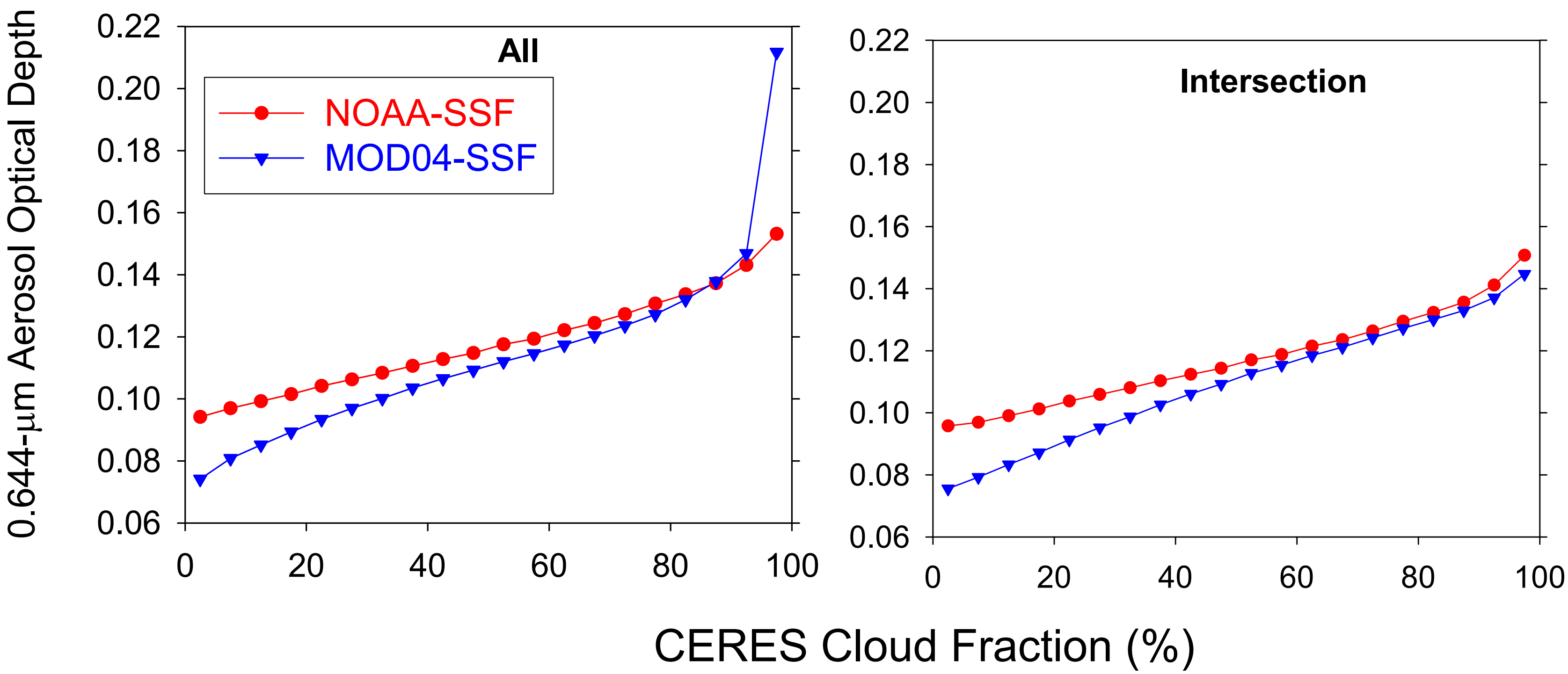
-Need advanced measurements in neighborhood of clouds.

-Summary.

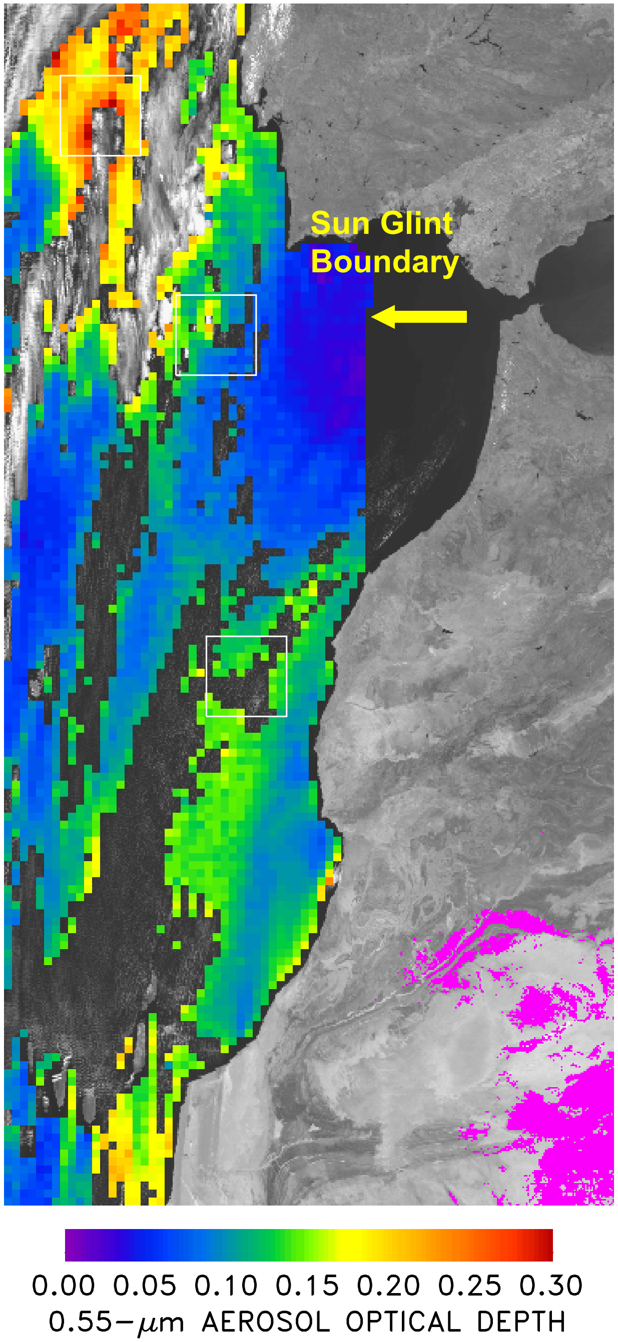
Cloud and aerosol correlation: What's the reason?

- Recent satellite studies have shown correlations between aerosol optical depth and cloud cover (Ignatov et al. 2005; Loeb and Manalo-Smith 2005; Kaufman et al. 2005; Matheson et al. 2006).

0.644-µm Aerosol Optical Depth vs Cloud Fraction (JJA 2000)



Loeb & Manalo-Smith (JCL, 2005)

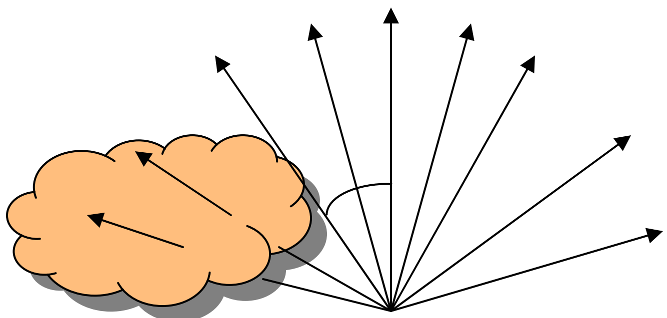


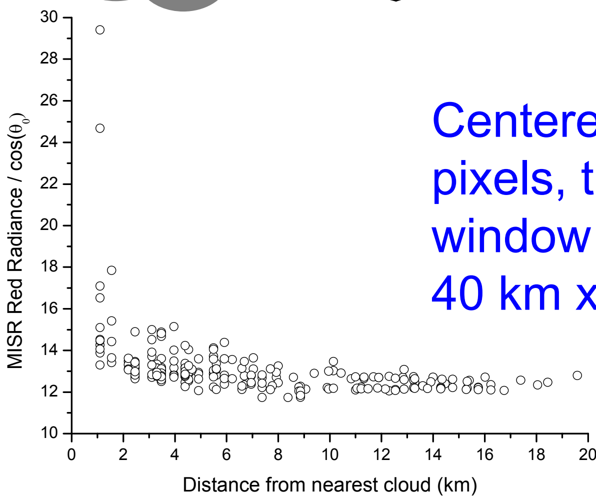
MODIS Aerosol Optical Depth and Cloud Cover

Jim Coakley

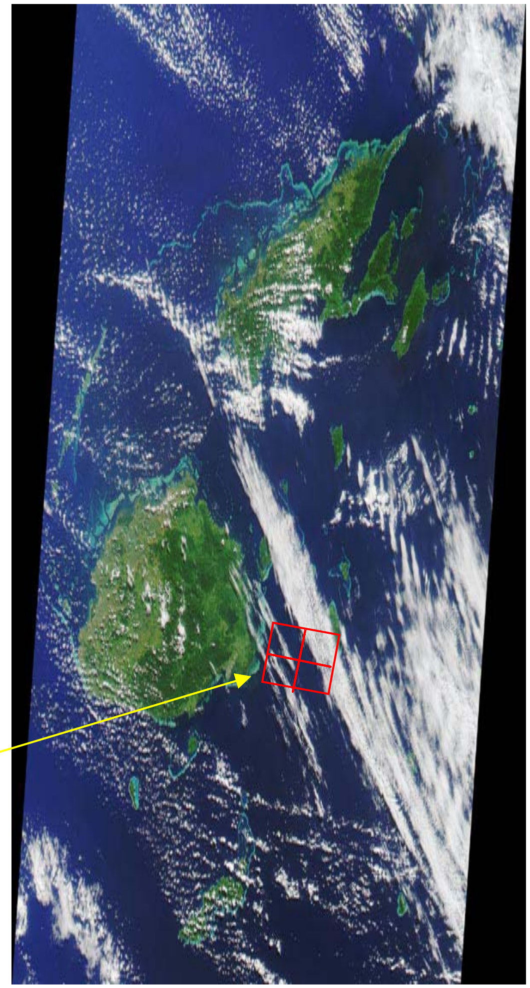
Using MISR cloud mask and radiance data to see clear-pixel radiance as a function of distance from nearest cloud

Cloud edge MISR viewing angle is saved

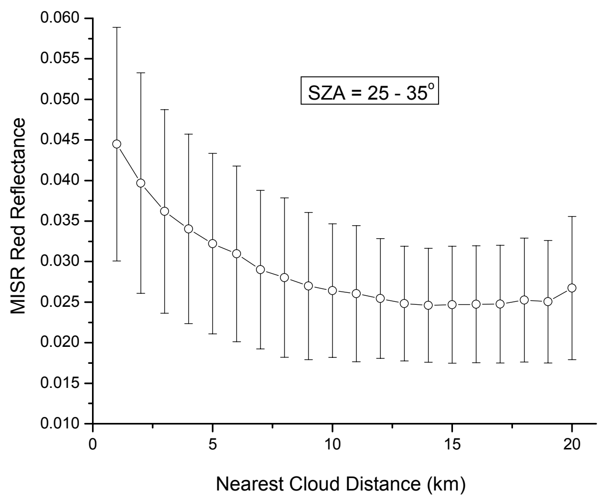


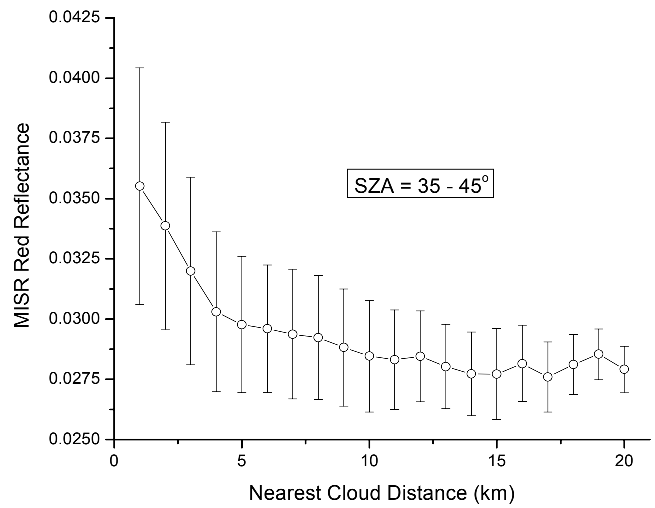


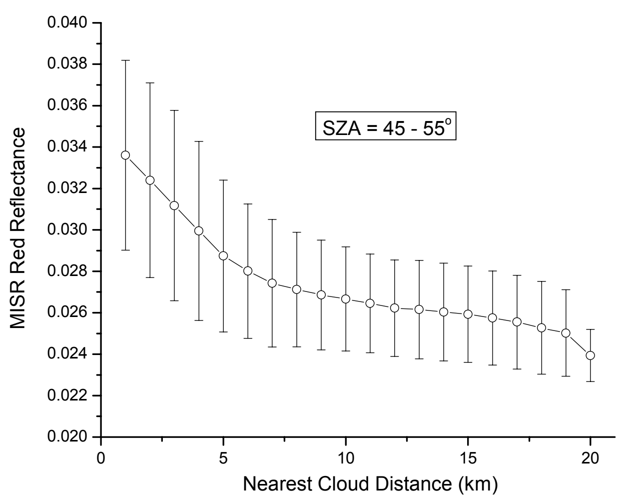
Centered at clear pixels, the working window covers ~ 40 km x 40 km area

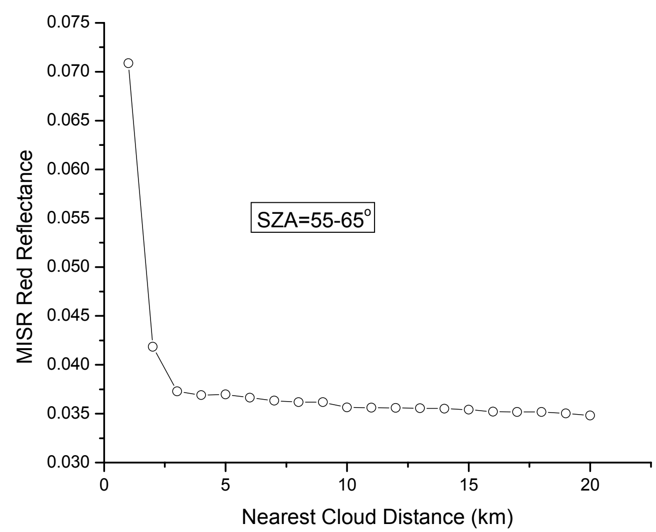


MISR nadir reflectance as a function of distance from cloud









Possible Reasons

- Aerosols are precursors to cloud formation.
- Aerosols grow in humid environments near clouds

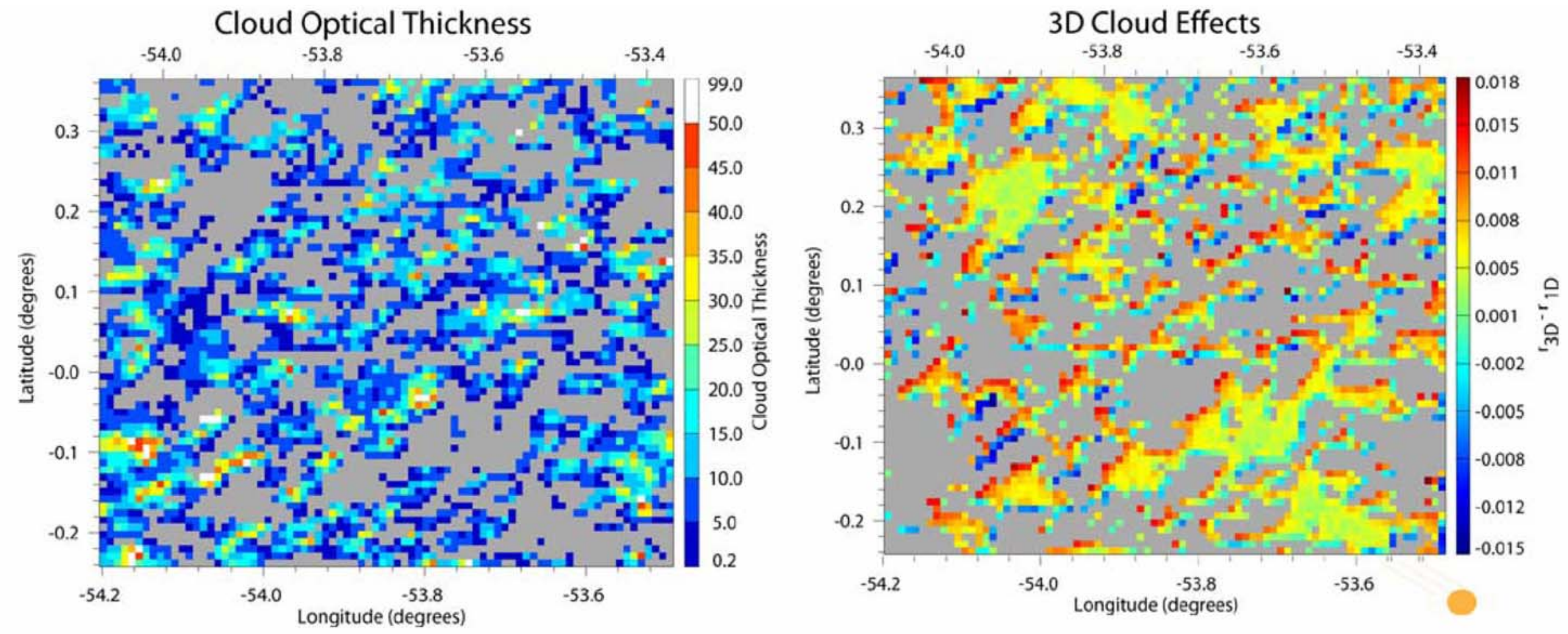
. Aerosols grow through in-cloud processing.

- New particle production in the vicinity of clouds.
- Illumination of particles enhanced by scattering of sunlight by clouds.
- Cloud contamination of the cloud-free pixels used to obtain aerosol properties.

Clearly, what happens to aerosols in the vicinity of clouds needs to be understood.

Jim Coakley

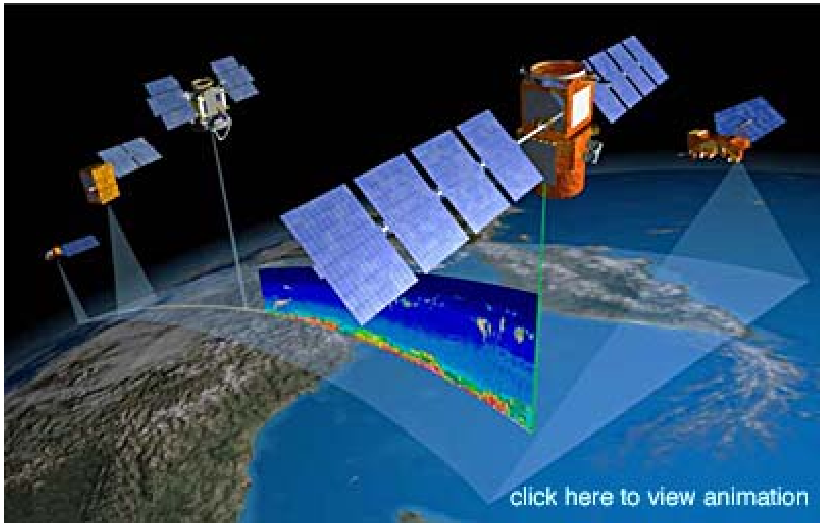
3D Radiative Effects of Cloud on Reflectance of Clear Pixels



3D radiative enhancement results in an overestimate of AOD of 0.04 in 1-D retrieval

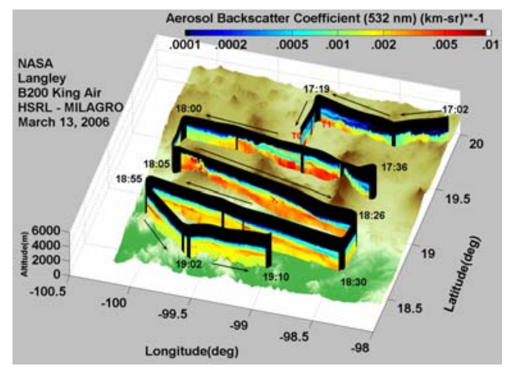
Wen et al. 2006

Active measurement can avoid 3D and cloud contamination effect



CALIPSO

Airborne HSRL

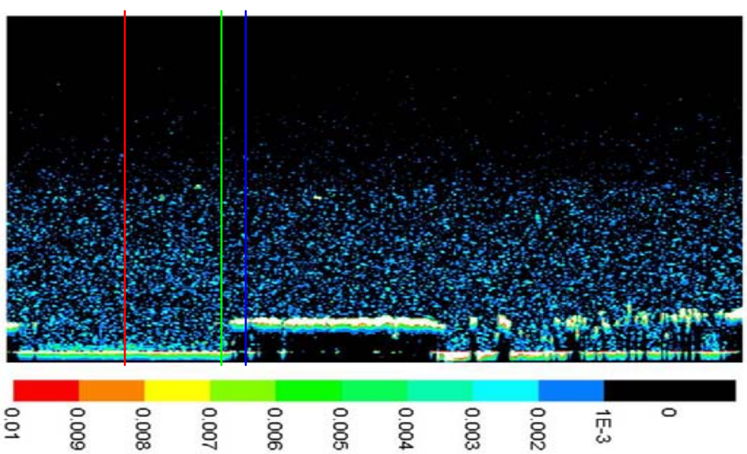


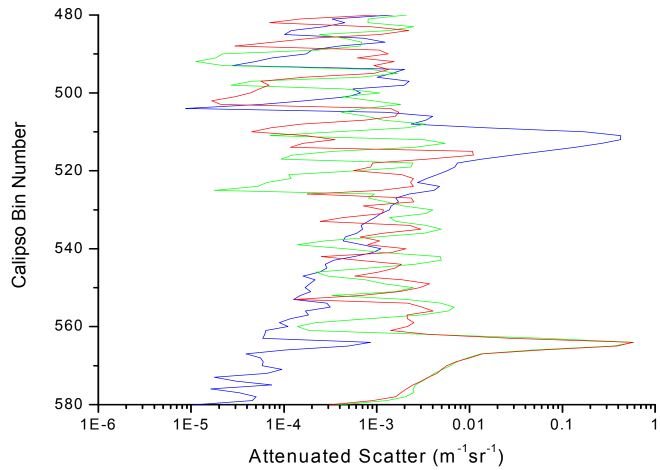
Chris Hostetler, John Hair, Richard Ferrare, Anthony Cook, David Harper, David Flittner, Yongxiang Hu, Michael Pitts, NASA Langley Research Center, Hampton, VA;

<u>Funded by</u>
NASA HQ Science Mission Directorate
Radiation Sciences Program
NASA ESTO
Department of Energy Atmospheric Science Program

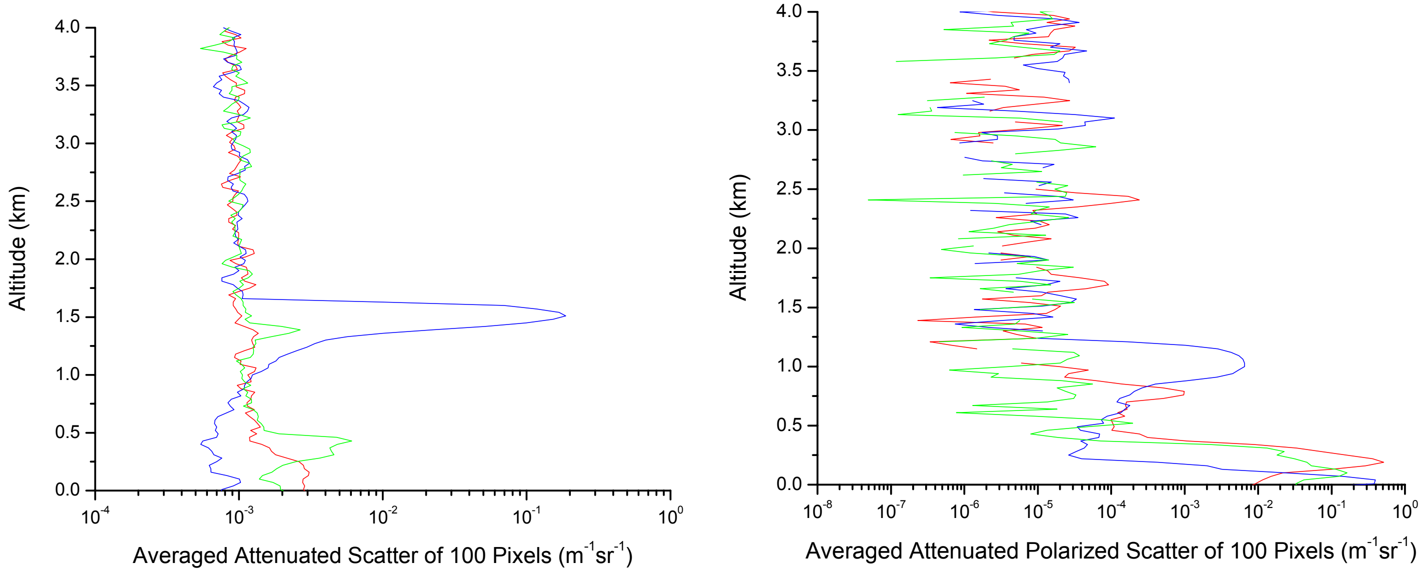
What does CALIPSO attenuated scatter show?

CALIPSO attenuated scatter [1/(m sr)]



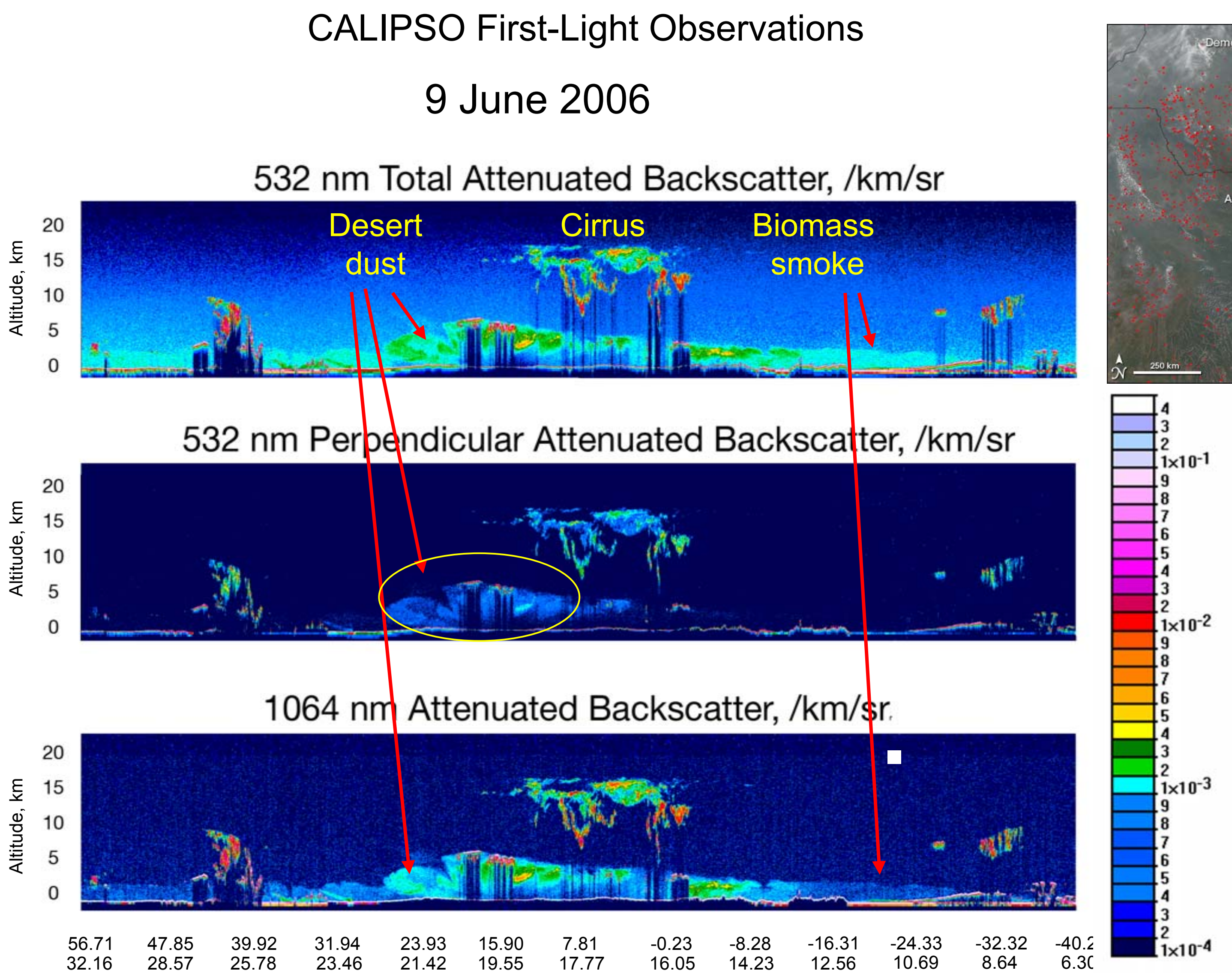


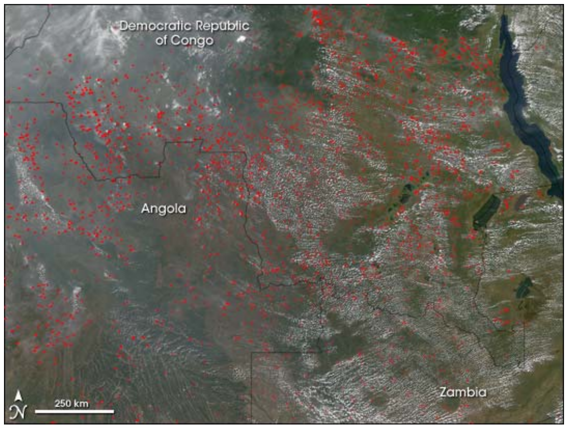
CALIPSO attenuated scatter profiles at different distance from cloud. Red: far; Green: near; Blue: cloud.



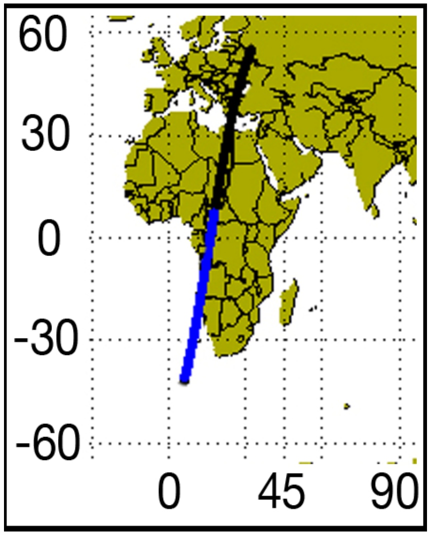
Averaged CALIPSO attenuated scatter profiles at different distance from cloud. Red: far; Green: near; Blue: cloud.

CALIPSO can show large-scale and significant cloud / aerosol process

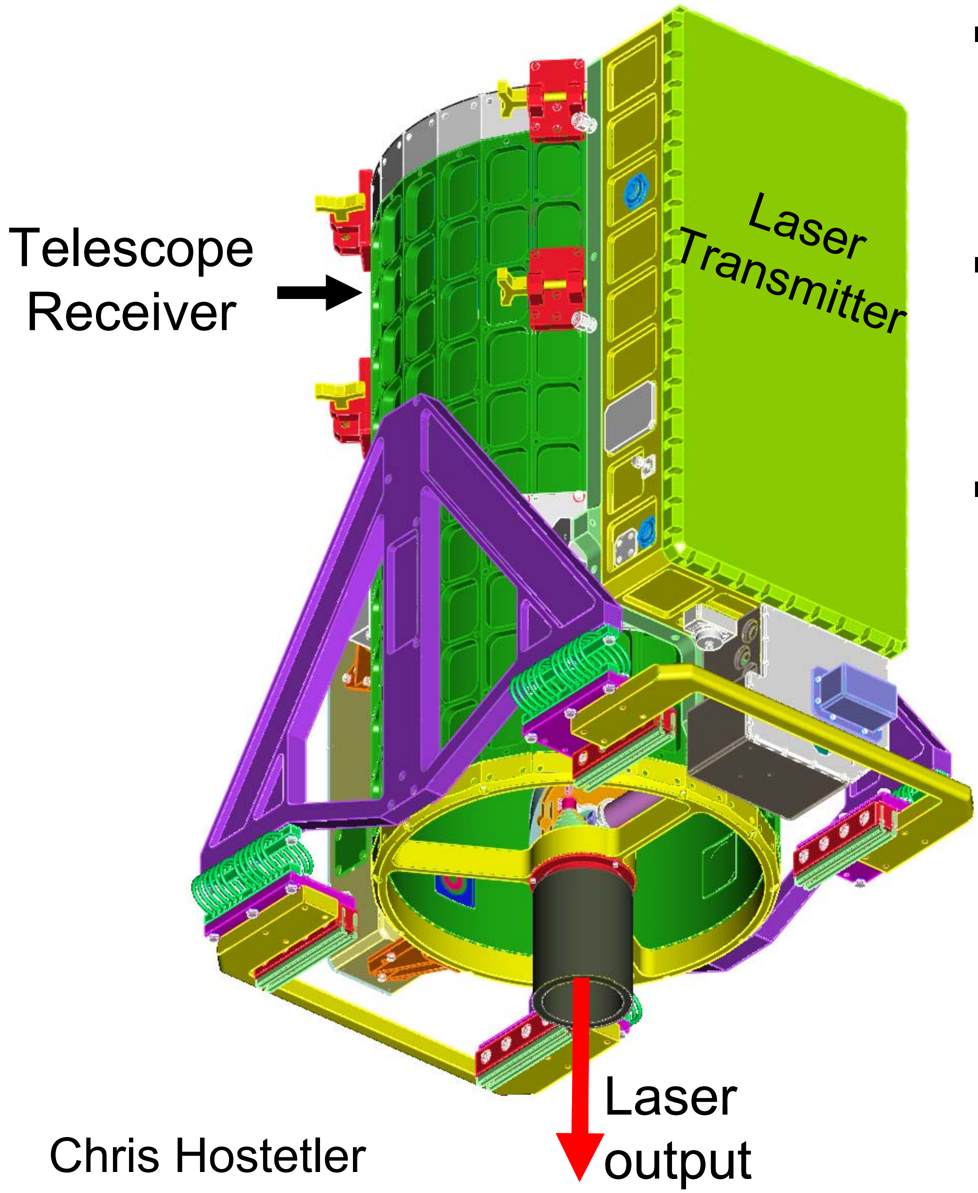




Fire locations in southern Africa from MODIS, 6/10/06



Airborne High Spectral Resolution Lidar (HSRL)



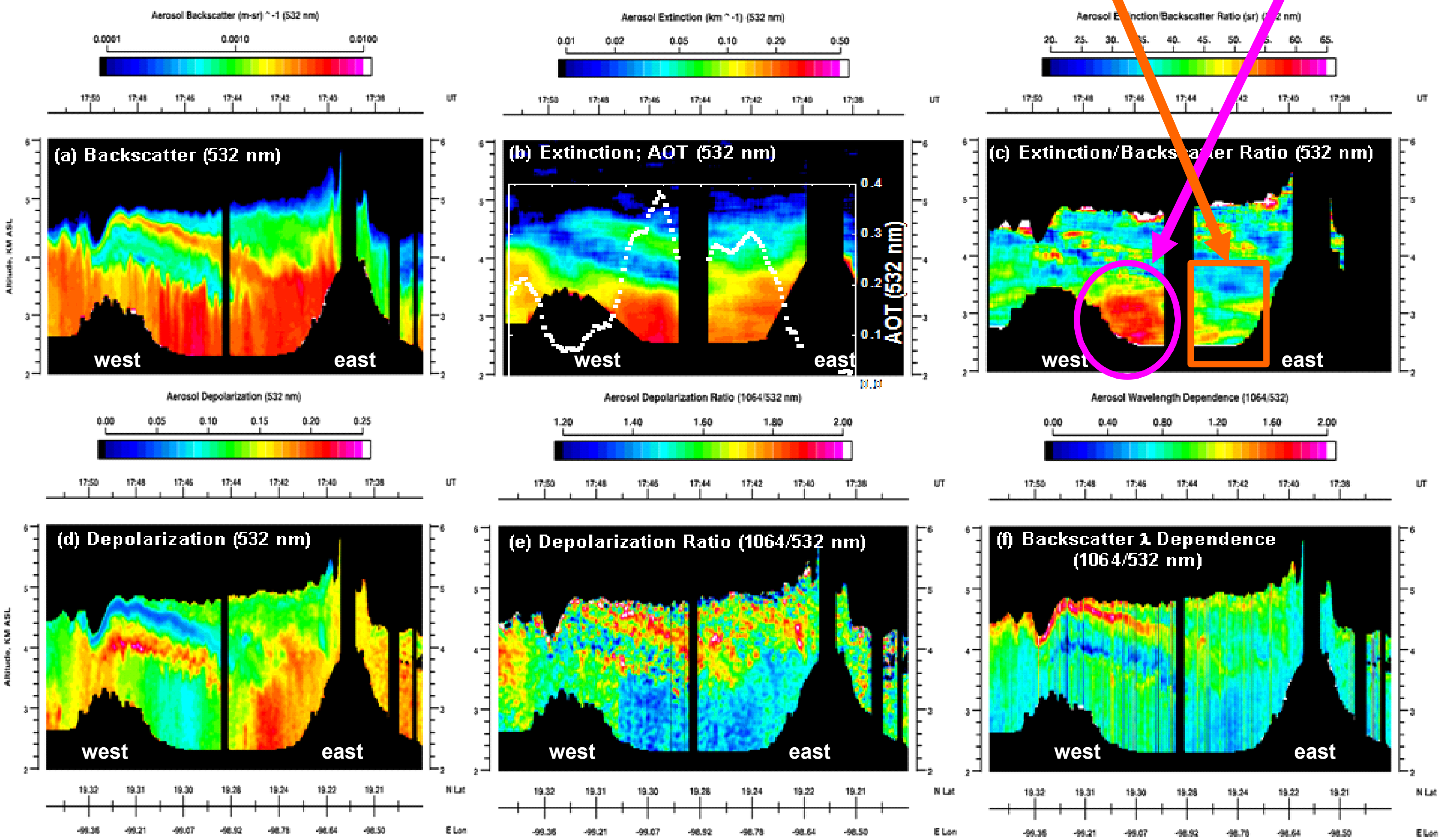
Chris Hostetler

- Focused on providing quantitative measurements of aerosol optical properties
- Different from standard backscatter lidars: independently measures backscatter and extinction (532 nm)
- History
  - 2000-2004: instrument development and integration
  - Dec 2004: first test flight on Lear 25-C
  - Dec 2005: first test flight NASA Langley King Air
  - >200 flight hours with instrument since completion, including
    - 60 hours on MILAGRO/MAX-MEX
    - 45 hours on CALIPSO validation (East US)
    - 90 hours on 2006 TexAQS/GoMACCS/MAX-TEX

Airborne High Spectral Resolution Lidar (HSRL) may work for twilight zone

LaRC Airborne HSRL Measurements over Mexico City, March 13, 2006

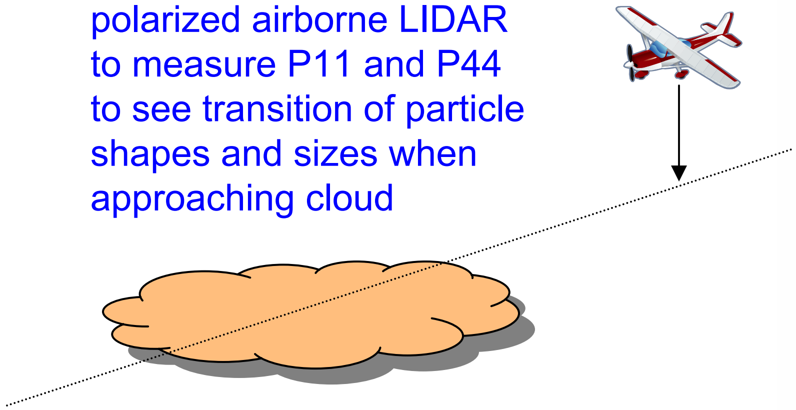
- western part of city- high S_a, high WVD, low depolarization – urban aerosol
- eastern part of city - low Sa, low WVD, high depolarization – dust



Chris Hostetler

Need advanced measurements in neighborhood of clouds

Proposal: Using circularly-polarized airborne LIDAR to measure P11 and P44 to see transition of particle shapes and sizes when approaching cloud



W. Sun et al. / Journal of Quantitative Spectroscopy & Radiative Transfer 79–80 (2003) 1083–1090 1087

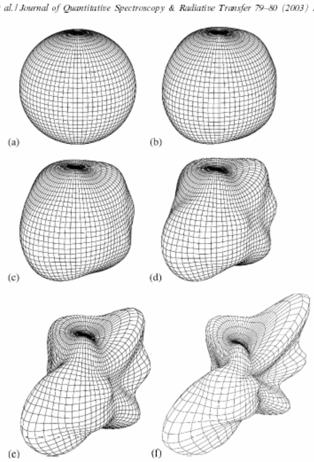


Fig. 1. Sample Gaussian particle shapes.

illustrated in Fig. 1. The incident wavelength $\lambda = 0.55$ μm and the refractive index of ice at this wavelength is $N = 1.311$. The particle size parameter $x = 2\pi a/\lambda = \pi$, where a denotes the mean radius of the particle. In the FDTD calculation, a spatial cell size of $\lambda/20$ is used. We can see that with the increase of the surface deformation, the strong oscillations in the conventional phase function (P11) gradually disappear. The degree of linear polarization P12/P11 also shows an even trend with the increase of surface deformation, which means the linear polarization properties of irregular ice crystals are significantly different from those of spherical cloud particles. Measurements of the phase function and degree of linear polarization for El Chichon, Pinatubo, and Lokon volcanic ashes at $\lambda = 633$ nm show similar results [33]. The difference in linear polarization property may help to

Measure I & V for particle shape & size

V / I = P44 / P11

If there is no shape & size change: No swelling
Otherwise: Swelling

1088 W. Sun et al. / Journal of Quantitative Spectroscopy & Radiative Transfer 79–80 (2003) 1083–1090

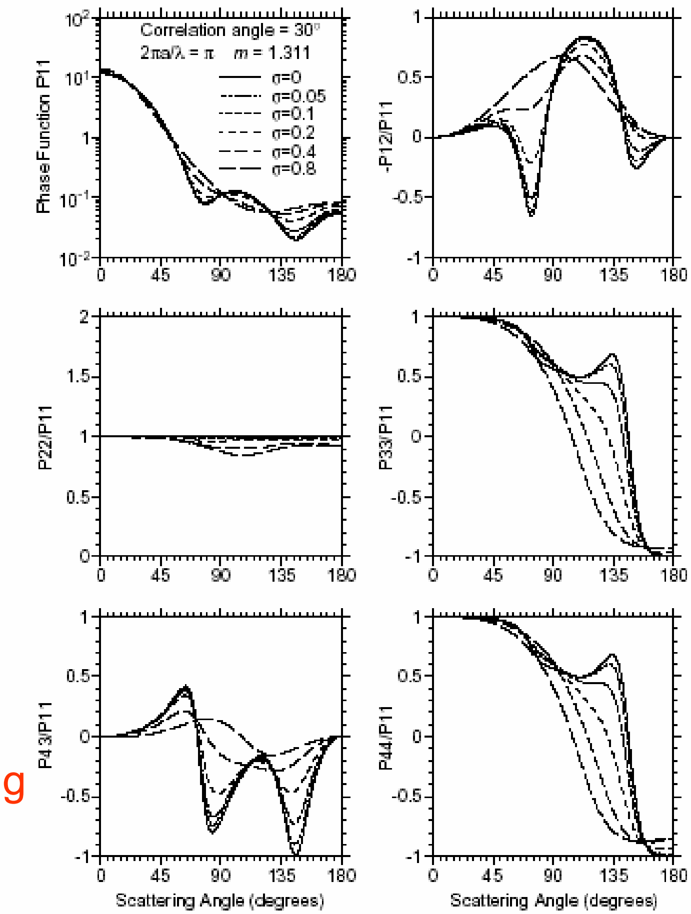


Fig. 2. The non-zero elements of the scattering phase matrix as functions of scattering angle calculated with the FDTD technique for randomly oriented Gaussian particles illustrated in Fig. 1. The incident wavelength $\lambda = 0.55$ μm and the refractive index of ice at this wavelength is $N = 1.311$. The particle size parameter $x = 2\pi a/\lambda = \pi$, where a denotes the mean radius of the particle. In the FDTD calculation, a spatial cell size of $\lambda/20$ is used.

Summary

1. Satellite data suggest aerosol-cloud correlations: Cloud cover increases with aerosol optical depth.

2. In the neighborhood of clouds, 3D cloud radiation effect, undetected cloud, and aerosol humid swell all can affect aerosol retrievals, and contribute to aerosol-cloud correlations

3. Using active measurements can avoid 3D effect and detect clouds missed in passive measurements.

4. How to separate humid swelling effect and indirect effect?

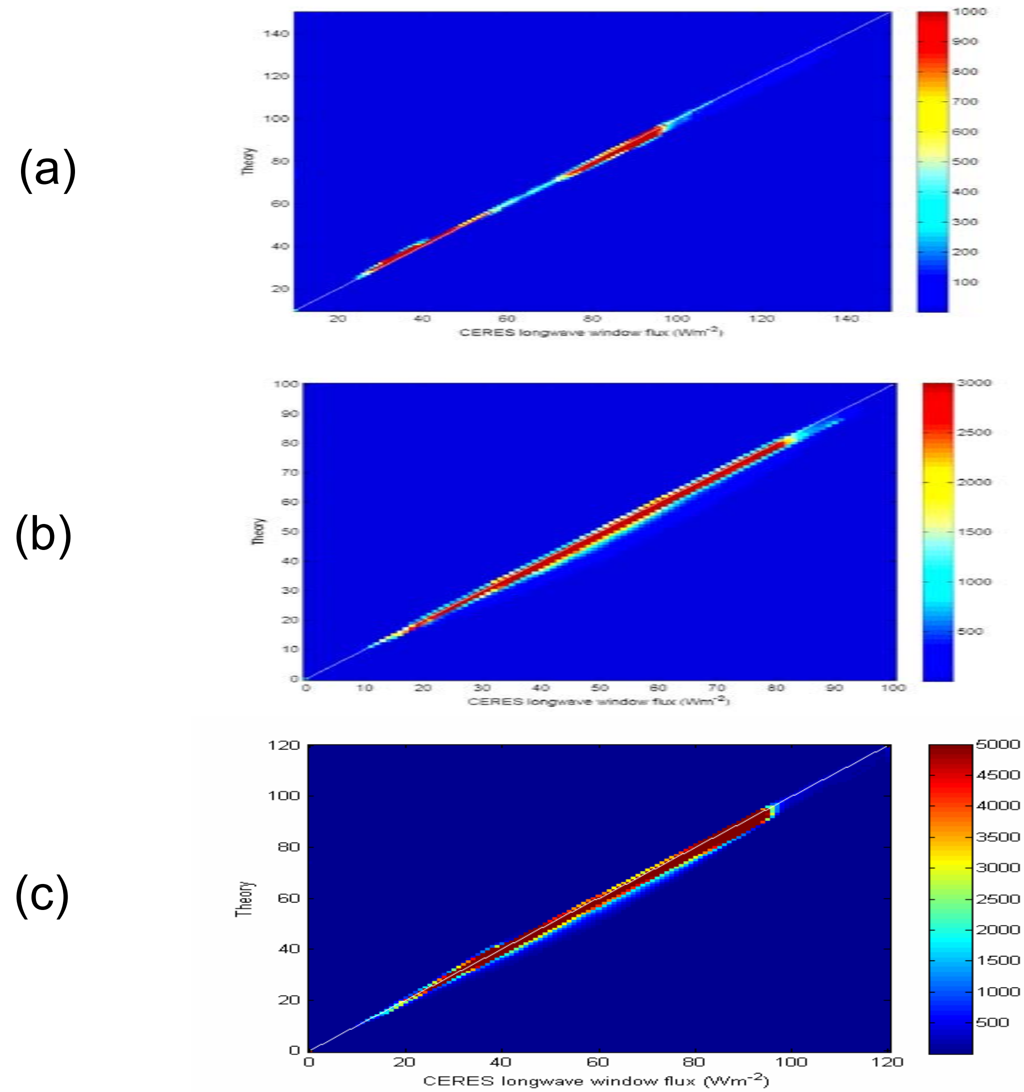
Presentations in CERES TOA Flux/ADM WG Meeting

1. Using CERES Window Data to Validate Diffusivity Approximation Theory

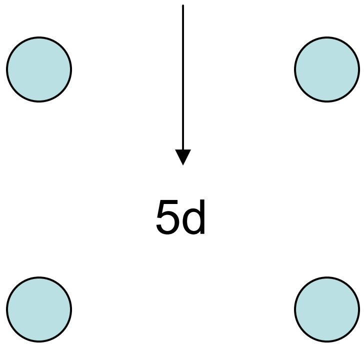
   Wenbo Sun, Yongxiang Hu, Norman G. Loeb, Bing Lin, and Marty Mlynczak

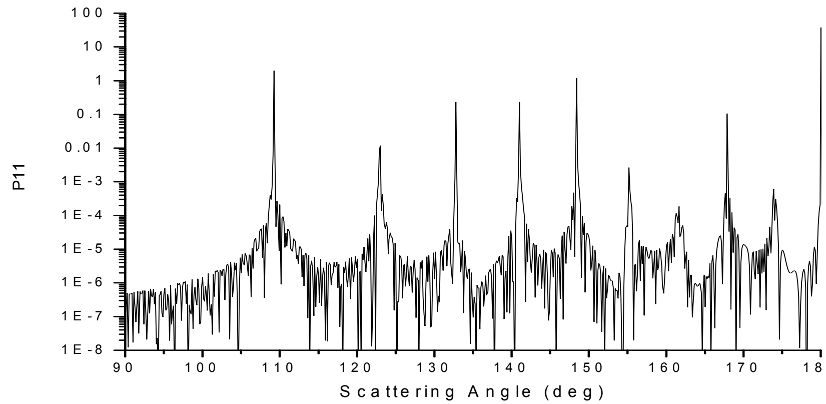
2. Can DISORT Simulate Reflectance from Snow?

   Wenbo Sun and Norman G. Loeb

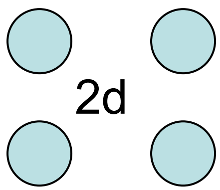


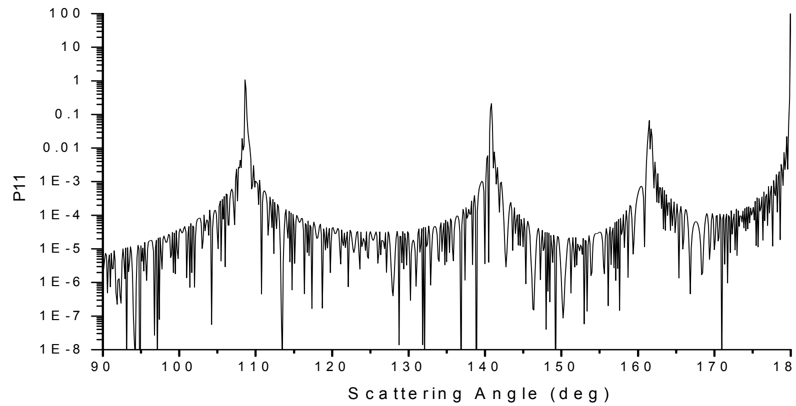
Comparisons of the window fluxes for (a) clear sky, (b) overcast clouds, and (c) all-sky, from the diffusivity approximation theory and CERES WN ADMs for 31 days of January 2005 for latitudes between 75 deg S and 75 deg N. The color bar shows the occurrence frequency of the samples.





When distance increases More peaks are expected, i.e. more Lambertian.





When distance decreases fewer peaks are expected, closer to rough surface scattering